1 March 1967

U. S. ARMY TEST AND EVALUATION COMMAND
COMMON ENGINEERING TEST PROCEDURE

3820

# METEOROLOGICAL EQUIPMENT, BALLOONS

## 1. OBJECTIVE

The objective of this MTP is to determine, under controlled and carefully monitored conditions, physical characteristics, technical qualities, and reliability of inflatable balloons designed for meteorological flights.

## 2. BACKGROUND

Meteorological balloons are in three categories: (1) Pilot balloons, used to determine wind direction and speed aloft; (2) Ceiling balloons, used to determine cloud height; and (3) Sounding balloons, used to carry equipments which send to ground receiving stations various thermodynamic parameters of the atmosphere. Its space position as determined by the ground tracking equipment permits calculations of wind data.

The seemingly simple meteorological balloon is in fact a rather complex fabrication. In addition to the basic neoprene latex, a balloon film contains such materials as plasticizers, accelerators, anti-ozonants, and reinforcing agents. The film must have elongation, modulus and tensile strength characteristics to achieve the desired height and rate of rise requirements and to permit inflation and launching and handling and wind buffeting without damage. Meteorological balloons must perform in weather extremes of temperature, precipitation, and winds.

Use and testing of balloons of varied materials, sizes, and lift capabilities have proceded as new items or new requirements were made. The present trend is to develop a satisfactory fast-rise balloon. The requirement for a fast-rise balloon is two fold: (1) It will cut down the time needed for each flight, and (2) It will permit more accurate and complete data to be received from radiosondes launched when strong jet stream wind conditions exist since it will reduce low tracking angles. Low tracking angles can mean distorted transmitting signals because of ground reflections and also data deterioration because of the trigonometric nature of the data reduction technique used.

## 3. REQUIRED EQUIPMENT

a. Balloon inflating equipment (nozzles, weights, hoses, valves, gauges).
b. Hydrogen generator, hydrogen cylinder, helium cylinder (as required), and cylinder of dry nitrogen.
c. Environmental test chamber (with instrumentation for measuring and recording instantaneous pressure and temperature)
d. Patch box and manometer
e. Gas meter
f. Air compressor and blower

g. Neck size cylinders
h. Measuring instruments (linear and thickness)
i. Weighing scales
j. Solar radiation lamps
k. Flexible scales
l. Balloon inflation table

4. REFERENCES

A. Elementary Meteorology, Taylor, 1957.
B. General Meteorology, Byers, 1944.
C. Meteorological Instruments, Middleton and Spilhaus, 1953 (revised 1960).
D. TM 11-2405, Meteorological Balloons and Inflation and Launching Accesories, Department of the Army, 1957.
E. AR 700-68, Safe Handling, Storing, Shipping, Use and Disposal of Compressed Gas Cylinders.
F. American Meteorological Society, Compendium of Meteorology, 1951.
G. MIL-B 10743D, Balloons, Pilot and Ceiling.
H. MIL-B 55087A, Balloon, Meteorological.
I. MTP 6-2-500, Physical Characteristics.
J. MTP 6-2-503, Reliability.
K. MTP 6-2-507, Safety.

5. SCOPE

5.1 SUMMARY

This MTP is comprehensive and includes evaluation of material, uniformity of neck size and dimensions, bursting diameter, shape, weight, and workmanship as outlined in MIL-B-10743D, 24 September 1963 and MIL-B-55087 A, 29 October 1959 (C1 27 January 1964). It describes the following subtests:

a. Physical Characteristics. This subtest shall weigh and measure the physical dimensions of the test item.
b. Technical Characteristics. This subtest shall measure and determine compliance with military specifications.
c. Burst Test. This subtest shall measure and determine dimensions (diameter) of the balloon at maximum inflation (burst).
d. Aging Effect Test. This subtest shall investigate shelf life and effects of aging on performance.
e. Reliability. This subtest shall determine dependability of performance as one-mission items.

5.2 LIMITATIONS

This MTP applies to ceiling, pilot, and sounding balloons used for meteorological purposes. It does not include captive and constant-level type balloons.

## 6. PROCEDURES

### 6.1 PREPARATION FOR TEST

a. Select an environmental test chamber using the following criterion:

1) The volume of the test facility must be such that the balloon under test may be expanded to a diameter of at least 32 feet without interfering with the generation and maintenance of test environmental conditions.
2) All apparatus used in conducting these tests must be capable of producing and maintaining the test conditions required.

b. Select test equipment having an accuracy of at least 10 times that of the function to be tested.

c. Record the following information:

1) Nomenclature, serial number(s), and manufacturer's name of the test item(s).
2) Nomenclature, serial number, accuracy tolerances, calibration requirements, and last date calibrated of the test equipment selected for the tests.

d. Assure that all test personnel are familiar with the required technical and operational characteristics of the item under test, such as stipulated in Qualitative Materiel Requirements (QMR), Small Development Requirements (SDR), and Technical Characteristics (TC).

e. Review all instructional material issued with the test item by the manufacturer, contractor, or government, and familiarize all test personnel with the contents of such documents. These documents shall be kept readily available for reference.

f. Prepare record forms for systematic entry of data, chronology of test, and analysis in final evaluation.

g. Assure that qualified safety personnel maintain a continuous observation of the test item through the entire test period to include either unsafe conditions or practices related to the use of the test items.

NOTE: It will be noted that the use of hydrogen or helium gas has not been specified in this MTP. However, since one of these gases will undoubtedly be used, it is important that test personnel be knowledgeable of the hazards involved and recognize the dangers connected with common malpractices associated with gas generators and compressed gas cylinders. TM 11-2405 (Ref D) and AR 700-68 (Ref E) not only contain ample discussion of these hazards and practices but also enumerate appropriate procedures to follow whenever the more common malfunctions occur. All test personnel must be thoroughly trained in the precautions and practices covered by these references.

h. Perform a pretest inspection of each test balloon as follows:

1) Using a blunt object, to avoid cutting into the balloon film, open the box containing the balloons and dump the balloon in its plastic bag onto the balloon inflation table.
2) Open the plastic bag completely using the rip strip or tear seal provided and let the balloon roll out onto the inflation table.

CAUTION: Extreme care must be exercised during all phases of handling the balloon to avoid damage to the film. Never lay the balloon out on a concrete floor. Light cotton or rubber gloves should be worn when handling the balloon to exclude the possibility of skin oils deteriorating the rubber of the balloon film.

3) Inspect the balloon for holes and reject any balloon having holes in the film. (Since discoloration does not affect balloon performance, holes in the balloon film shall be the only basis for rejection).

i. Pre-condition each test balloon as follows, unless otherwise specified in a specific test:

1) Balloons less than one year old which have not been exposed to temperatures of zero degrees Celsius (C) or below shall not require conditioning.
2) If a test item which is less than one year old has been subjected to low temperatures, (zero degrees Celsius (C) or below) expose it in its container to an ambient temperature of approximately 20 degrees C for 24 hours.
3) Condition balloons that are more than one year old in a hot, humid chamber for a minimum of 12 hours. If the chamber is not available, immerse the balloon in boiling water for about 5 minutes. Use the balloon as soon as possible thereafter. If the temperature at ground level is above 5 degrees C the balloon can be used while still wet. If the temperature is below 5 degrees C, dry the balloon in a warm area prior to test.

## 6.2 TEST CONDUCT

### 6.2.1 Physical Characteristics

As each balloon in removed from its container for a specific test, perform the following:

a. Measure the maximum diameter of each test item when deflated to 0.5 inch and record on a suitable data form.

b. Weigh each test item to one-half gram accuracy and record on a suitable test form.

NOTE: Weight shall include that of talc or equivalent dusting material provided that any amounts in excess of that required for adequate protection against adherence of balloon folds shall be emptied before weighing.

c. Perform a visual inspection of each test item and record:

1) Condition of material as to color and flexibility
2) Adequacy of dusting material as a covering preservative
3) Any adherence between folds of the balloon

6.2.2 Technical Characteristics

6.2.2.1 Neck Characteristics

a. Select five items at random from the test sample of each type of balloon.

b. Measure and record the length of the tubular (approximately constant cross sectional area) portion of neck of each balloon.

c. Measure and record thickness of neck material at ten different points (if the measurements are made of a double thickness of the neck, ensure the neck if flattened so that a true measure is obtained of only the two neck thicknesses and use one-half that value).

d. Measure neck inside diameters by fitting them over rigid tubes or cylinders of circular cross section. For each size balloon, two gages of maximum and minimum neck diameters shall be used (see appropriate military specifications). The necks shall fit the gages of minimum diameter without stretching, but shall require stretching to fit the gages of maximum diameter. Record neck inside diameters on a suitable data form.

e. Measure the neck strength of sounding balloons by subjecting them to the application of five-pound increments to a total of forty pounds. The forty-pound load shall be accepted for a period of one minute without rupture or separation from the balloon. Record neck strength measurements on a suitable data form.

6.2.3 Physical Properties

a. Fabricate an elongation and tensile measurement test apparatus as follows:

1) Patch box - A cylindrical, hinged box similar to that shown in Figure 1, which provides a means for clamping the specimen so that it has a circular exposed area having a diameter of 2.50 inches. The box shall include a valve connection to a source of dry nitrogen.
2) The valve (connection) for the nitrogen supply shall be a cut-off type so that the patch box can be removed from the

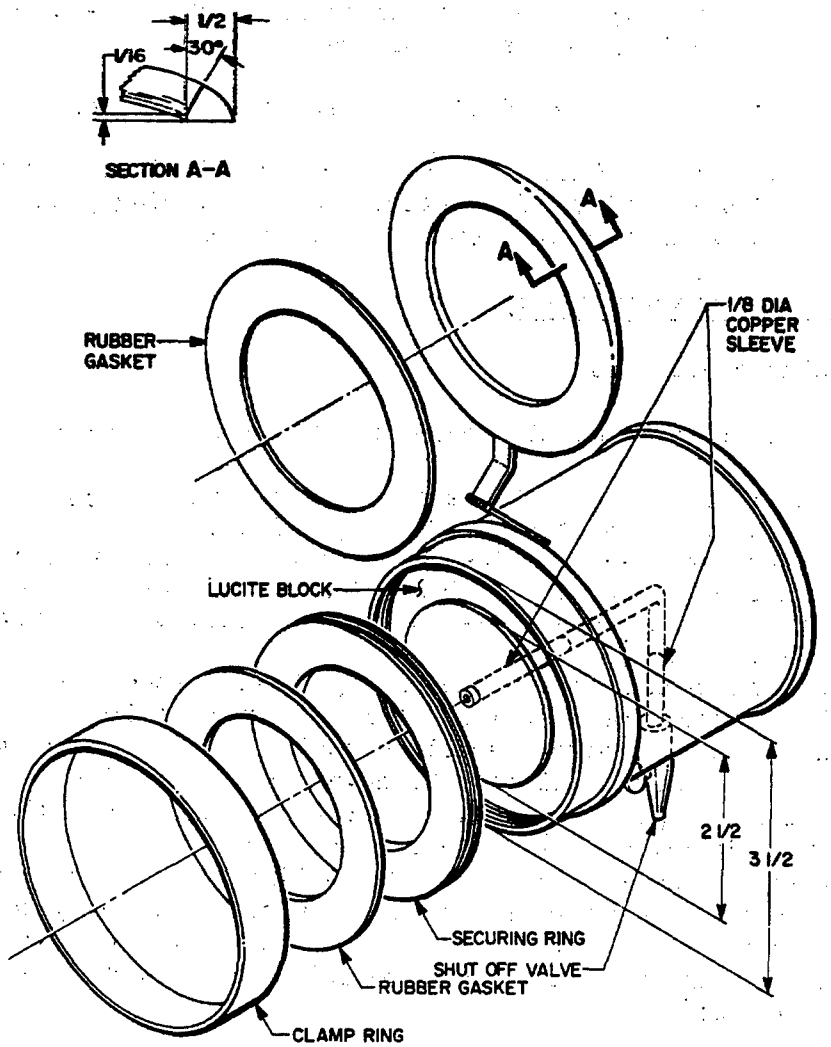


Figure 1—Patch Box

nitrogen supply.

3) A flexible scale shall be so oriented that it passes over the pole (central point) and conforms to the shape of the patch during inflation for measurement of the increase in diameter of a one centimeter circle inscribed in the center of the patch.
4) Two freely moving flat-headed pistons shall be situated to be pushed outward as the patch inflates for measurement of the major patch (bubble) diameter at 600 percent elongation and burst.
5) A manometer or bellows shall be connected to a suitable electrical measuring device for measuring the pressure in the patch box.

b. Cut nine square patches, 5-inches by 5-inches, from each of any three of the five balloons of each type previously selected in paragraph 6.2.2.1 above, as follows:

1) Three patches from the area near the neck
2) Three patches from the area opposite the neck
3) Three patches from the balloon equator

c. Subject three specimens from each balloon to accelerated aging for eight hours by placing them in a dry oven set at 100-degrees C, plus or minus 5-degrees. (NOTE: Specimens shall be kept in a dessicator for a minimum of 24 hours after removal from the oven, but tests shall be conducted within 96 hours after removal from the oven).

d. Clamp three patches from each balloon (not aged) in the patch box and inflate each patch at a rate which will cause burst after 15 to 20 minutes.

e. As the patches are being inflated to burst, measure elongation, tensile strength, and tensile stress for each patch and record on a suitable data form.

NOTES: 1. Tensile stress shall be measured and determined at 600 percent elongation.
2. Tensile strength shall be defined as the pressure required to cause the specimen to burst.

f. Repeat Steps (d) and (e) above, using the three patches aged in step (c) above.

g. "Soak" the three remaining specimens from each balloon (at a temperature of minus 70 degrees C, plus or minus one degree) for a period of eight hours in a low temperature cabinet having the following characteristics:

1) A refrigerated work space of approximately two feet by two feet
2) A door of the front opening type containing a five ply thermopane window or its equivalent to permit observation of the test sample during the test

3) Capability of maintaining a constant temperature of minus 70 degrees C plus or minus one degree
4) The cabinet shall be equipped with a means of elongating a specimen to "rupture"
5) The rate of inflation shall be such that rupture occurs in fifteen to twenty minutes

h. At the conclusion of the eight hour soaking period, inflate each patch to burst, measure elongation, tensile strength and tensile stress, and record on a suitable data form.

6.2.4 Burst Tests

6.2.4.1 Pilot and Ceiling Balloons

a. Obtain a test sample (of at least 80) of each type of pilot and ceiling balloons, and divide the sample into four sub-samples or lots. Designate the lots A, B, C, and D for ease of reference. These lots should be composed of even numbers of test items.

b. Subject the sub-sample lots to various sequences of temperature prior to test as follows:

1) Place lots A and B in a cold chamber for 72 hours at an average temperature of minus 20 degrees C. (minus 40°C to zero degrees C)
2) Place lots C and D in a heated chamber (50° to 60°C) for 24 hours
3) Place lot C in the cold chamber (after cooling to normal temperature) as in (1) above
4) Place lot B in the heated chamber (after warming to normal temperature) as in (2) above

c. While the above temperature conditioning is taking place, arrange a test setup, containing one fixed and one movable vertical plane surface, to determine diameter at time of burst.

NOTES:
1. As inflation proceeds the balloon shall be maintained in very light contact (just tangent) with the fixed vertical surface (such as a wall).
2. The moveable surface shall be kept just tangent to the opposite balloon surface as it is moved along a measured, graduated scale while inflation proceeds.
3. Inflations shall be accomplished with compressed air as indicated in the procedure and continued until the test item bursts.
4. The measured distances between the vertical surfaces shall be taken as the balloon diameter at burst. If a gas metering device is available, the volume of delivered air may be used as the balloon volume and the diameter of an equivalent sphere computed (see paragraph

6.4.3). In general, the actual balloon shape will not be spherical and the computation will be approximate but satisfactory for comparison.

d. Select a sub-sample lot (of at least 10) of either pilot or ceiling balloons, temperature conditioned as in step (b) above, and slowly inflate one-half of the balloons with air to burst. Note the diameter of each balloon at the time of rupture as outlined in step (c) above.

e. If the burst diameter of each balloon is within specifications, inflate the remaining half of the lot to burst, again noting each burst diameter. If all of the first half lot is not within specifications, condition the second half and then test.

f. Repeat steps (d) and (e) above, for each of the four sub-sample lots of pilot or ceiling balloons.

g. If more than 50 percent of the total balloons tested meet the military requirements for size at or before burst, repeat steps (d), (e), and (f) in a cold chamber.

NOTES: 1) As the balloons are inflated, reduce the chamber temperature to approximate the increasingly cold temperature of the upper air during flight. These temperatures (average minimums for heights involved) shall be obtained from the local Meterological Support Activity.

2) Solar radiation lamps shall be used continuously on one-half of each sub-sample to simulate daytime conditions.

h. Record the following values for each lot of balloons tested:

1) Volume of each balloon at burst
2) Diameter at burst
3) Distortion of shape during inflation
4) Temperature in test room
5) Rate of inflation
6) Time to burst
7) Temperatures in test chamber versus time
8) Pressures in test chamber versus time
9) Number of balloons tested
10) Number of balloons subjected to solar radiation
11) Time to failure of each balloon failed
12) Number of balloons successfully meeting mission requirements

i. Repeat steps (d) thru (h) above, using samples of pilot and ceiling balloons selected at random which have not been subjected to the temperature conditioning of Step (b) above.

6.2.4.2 Sounding Balloons

a. Obtain a test sample (of at least 80) of each type of sounding

balloons and subject them to temperature conditioning as described in Steps (a) and (b) of paragraph 6.2.4.1.

b. Install the following equipment within a test chamber which provides unobstructed expansion of a balloon to a diameter of at least 32 feet:

1) A blower capable of delivering air at atmospheric pressure at a rate of not less than 80 cubic feet per minute
2) An air volume meter reading in cubic feet
3) A nozzle of a size suitable for attachment to the balloon neck. The nozzle shall point vertically downward and snall be located at a height of not less than 32 feet above the testing floor.

c. Select a sub-sample lot of sounding balloons, temperature conditioned as in Step (a) above, and securely fasten the balloon to the inflation nozzle so that no air can escape around the neck of the balloon.

d. Calculate or measure the volume of gas required to provide lift at the start of the test.

e. Calculate the proper or necessary burst volume at the pressure exerted by the atmosphere at 110,000 feet, or the required minimum altitude for the test item as outlined in Appendix C.

f. Inflate the balloon at a rate of not less than 80 cubic feet per minute until the balloon bursts. (NOTE: When the balloon has been inflated to normal launch size, the inflation rate may be increased to simulate approximately one hour of flight time to burst).

g. Carefully observe the volume of air at burst as indicated by the air metering device, and the horizontal (equatorial) diameter of the balloon at burst as outlined in Step (c) of paragraph 6.2.4.1.

h. Repeat Steps (c) thru (g) above, for each of the four sub-sample lots of sounding balloons.

i. If more than 50 percent of the total balloons tested meet the military requirements for size at or before burst, repeat steps (c) thru (h) in a cold chamber as outlined in Step (g) of paragraph 6.2.4.1.

j. Record the following values for each lot of balloons tested:

1) Volume of each balloon at burst
2) Diameter at burst
3) Distortion of shape during inflation
4) Temperature in test room
5) Rate of inflation
6) Time to burst
7) Temperatures in test chamber versus time
8) Pressures in test chamber versus time
9) Number of balloons tested
10) Number of balloons subjected to solar radiation
11) Time to failure of each balloon failed
12) Number of balloons successfully meeting mission requirements

k. Repeat steps (c) thru (j) above, using samples of sounding balloons selected at random which have not been subjected to the temperature conditioning of step (a) above.

6.2.5 Aging Effect Tests

a. Randomly select subtest samples from balloon lots manufactured in the past which have been stored for at least six months under specified conditions of temperature and humidity, and perform Physical and Technical Characteristics tests as outlined in paragraphs 6.2.1 and 6.2.2.

b. Repeat Step (a) above with randomly selected balloon lots stored over a period of as much as five years. These lots shall be of random age in six-month age groups.

6.2.6 Reliability Tests

a. Since the test item in this MTP is a one-time type, its reliability refers to dependability of mission accomplished rather than repeated usage. Therefore, determine reliability from the results of subtests by taking the proportion or percentage which yield mission minimum results and record on a suitable data form.

b. Record all test results on the basis of "satisfactory" or "failure" on a suitable data form.

c. Divide data into categories of conformance to specifications and performance of mission and record on a suitable data form.

6.3 TEST DATA

6.3.1 Preparation for Test

Data to be recorded prior to testing will include but not be limited to:

a. Nomenclature, serial number(s) and manufacturer's name of the test item(s).

b. Nomenclature,serial number, accuracy tolerances, calibration requirements, and last date calibrated of the test equipment selected for the tests.

c. Appropriate photographs of the test item and installation

6.3.2 Test Conduct

6.3.2.1 Data to be recorded in addition to specific instructions listed below for each individual subtest shall include:

a. Photographs or motion pictures which will support test results or conclusions

b. An engineering logbook containing in chronological order, pertinent remarks and observations which would aid in a subsequent analysis of the test data. This information shall consist of temperature, humidity, and other appropriate environmental data, or other description of equipment or components and functions and deficiencies.

6.3.2.2 Physical Characteristics

The following items of data shall be recorded for each balloon:

a. Maximum diameter when deflated to 0.5 inch
b. Weight to one-half gram accuracy
c. Condition of balloon film
d. Amount of adequacy of dusting protective powder
e. Stickiness or coherence of balloon folds

6.3.2.3 Technical Characteristics

Measurements shall be made and recorded for each balloon as follows:

a. Type of balloon (ceiling, pilot, sounding)
b. Neck length to 0.5 inch
c. Neck wall thickness 0.025 min and 0.075 max. (See appropriate MIL Standard for criteria)
d. Neck inside diameter to 1 inch ± 1/8 inch
e. Record neck strength weight at which failures occur
f. Record successful tests and failures (neck strength)

6.3.2.4 Physical Properties

a. Record elongation, tensile strength and tensile stress data as follows:

1) Differential pressure at 600 percent elongation (manometer or gauge reading)
2) Equatorial radius of patch at 600 percent elongation
3) Radius of original exposed patch
4) Original thickness of balloon film patch
5) Differential pressure at burst (manometer or gauge reading)
6) Equatorial radius of patch at burst
7) Data will be taken on two sets of specimens. One set will not be aged. The second set will be aged.
8) The same data will be taken at minus 70 degrees C on one set of patches not aged

6.3.2.5 Burst Tests

The following items of data shall be recorded for each test condition:

a. Volume of each balloon at burst
b. Diameter at burst
c. Distortion of shape during inflation
d. Temperature in test room
e. Rate of inflation
f. Time to burst
g. Temperatures in test chamber vs. time
h. Pressures in test chamber vs. time
i. Number of balloons tested
j. Number of balloons subjected to solar radiation
k. Time to failure of each balloon failed

1. Number of balloons successfully meeting mission requirement

6.3.2.6 Aging Effect Tests

a. Record data on available stock of different age in storage
b. Record elongation and tensile strength
c. Maintain continuing data record on lots of same manufacture and same age

6.3.2.7 Reliability Tests

a. Record all test results on the basis of performance, using "satisfactory" or "failure" as the measure.
b. Data will be divided into categories of conformance to specifications and performance of mission.

| | Conformance to Specifications | Performance of Mission |
|---|---|---|
| Total Flights/Inflations | | |
| Failures or Non-completion | | |
| Tests without Aging | | |
| Tests with Aging | | |
| Percent Failure (Not Aged) | | |
| Percent Failure (Aged) | | |
| Percent Failure Overall | | |
| Percent Failure by Type | | |

6.4 DATA REDUCTION AND PRESENTATION

6.4.1 Physical Characteristics

a. All measurements shall be tabulated and processed to show:

1) Maximum
2) Minimum
3) Mean
4) Median

6.4.2 Technical Characteristics

a. Neck measurements shall be tabulated to show test items which

conform to specifications versus those which do not. Recorded data shall be evaluated to show:

1) Neck Size

a) No. of items measured
b) Average neck length
c) Median neck length
d) Minimum neck length

2) Interior diameter of neck

a) No. of items (small)
b) No. of items (large)
c) No. satisfactory

3) Membrane thickness standard

a) Average each balloon
b) Average for each sample
c) Maximum
d) Minimum
e) Median

b. Neck measurements shall be tabulated by numbers and sizes, showing totals in each dimension of measured data. Percentage of non-standard measurements shall also be shown.

c. Neck strength shall be presented as a graph showing numbers of balloon necks failing at each weight. Percentage failure shall also be shown.

6.4.3 Physical Properties

a. Elongation, tensile strength, and tensile stress data shall be reduced by formula to establish physical constants for the test sample. Computations are as follows:

1) Elongation

$$E_B = \frac{2.6\ R}{a}$$

where: $E_B$ = Elongation at burst

$R$ = Equatorial radius at burst

$a$ = Original radius of patch

2) Tensile Stress (modulus)

$$S_e = \frac{1.35\ PR_\varepsilon \times 2}{a\ t}$$

where: $S_e$ = Tensile stress at 600 percent elongation

P = differential pressure at 600 percent elongation

$R_E$ = equatorial radius of patch at 600 percent elongation

a = radius of original exposed patch

t = original patch (film) thickness

3) Tensile Strength

This computation uses the same formula as in (2) above, substituting:

P = differential pressure at burst

$R_E$ = equatorial radius at burst

4) Elongation at Minus 70 Degrees C

This computation uses the formula of (1) above.

b. Elongation shall be presented as a graph of computed values versus numbers of test items in each numerical class.

c. Tensile strength shall be presented as a graph of computed values versus test items.

d. Tensile stress shall be presented as a graph of computed values versus test items.

e. Elongation at minus 70 degrees C will be graphed on the same chart and in the same manner as in (e) above.

6.4.4 Burst Tests

a. Reduction - diameter of the equivalent sphere is determined from the gas volume at burst as follows:

$$V = \frac{4\pi}{3} r^3 \qquad D = 2r$$

$$r = \sqrt[3]{\frac{3v}{4\pi}} \qquad D = 2\sqrt[3]{\frac{3v}{4\pi}} = 2\sqrt[3]{\frac{21V}{88}}$$

$$D = \sqrt[3]{\frac{168V}{88}} = \sqrt[3]{1.9V}$$

For practical purposes and easiest computation, the value $D = \sqrt[3]{2V}$ is acceptable.

b. Presentation

| | Type | | Type | | Type | |
|---|---|---|---|---|---|---|
| | Aged | Not Aged | Aged | Not Aged | Aged | Not Aged |
| Maximum diameter* at burst | | | | | | |
| Minimum diameter* at burst | | | | | | |
| Average diameter* at burst | | | | | | |
| Median | | | | | | |

Ambient temperature for inflation shall be 25 degrees C ± 18 degrees.

Temperature of test chamber _____.

* Record to accuracy of 0.1 foot

6.4.5 Aging Effects Test

a. Comparisons shall be made between results on a single lot over a period of time.

b. All measured values shall be tabulated from inspection to inspection.

c. First order difference that vary from zero indicate changes due to time in storage.

6.4.6 Reliability Tests

This term, applied to confidence that a one-time mission will be performed with certainty, is presented as a single value. It may be presented for portion of the test such as for aged and for unaged items. It will cover a maximum of items in a single classification. The number of items will be shown on which the reliability figure is based.

# APPENDIX A

## Meteorological Equipment, Balloons

| Volume Cu. Ft. (STP) | Lift in Grams Hydrogen | Lift in Grams Helium |
|---|---|---|
| 1 | 33.83 | 30.85 |
| 2 | 67.66 | 61.70 |
| 5 | 169.15 | 154.25 |
| 10 | 338.30 | 308.50 |
| 20 | 677.60 | 617.00 |
| 100 | 3383.00 | 3085.00 |

Note: Other values may be determined by direct combination of given values.

APPENDIX B

Meteorological Equipment, Balloons

| Balloon Nomenclature | Type | Initial Volume (Cu. Ft) | Weight (Grams) | Total Lift (Gms) | |
|---|---|---|---|---|---|
| | | | | Hydrogen | Helium |
| ML-157-A | Ceiling | 1.6 | 10 | 54 | 49 |
| 158-A | | 1.6 | 10 | do | do |
| ML-50-A | Pilot | 5.1 | 30 | 173 | 157 |
| 51-A | | 5.1 | 30 | do | do |
| 64-A | | 5.1 | 30 | do | do |
| 155-A | | 5.1 | 30 | do | do |
| 156-A | | 5.1 | 30 | do | do |
| 159-A | | 21.2 | 100 | 717 | 650 |
| 160-A | | 21.2 | 100 | do | do |
| 161-A | | 21.2 | 100 | do | do |
| ML-131-A | Sounding | 90 | 350 | 3045 | 2775 |
| 391/AM | | 130 | 1400 | 4398 | 4000 |
| 391A/AM | | 120 | 1400 | 4060 | 3695 |
| 391B/AM | | 120 | 800 | 4060 | 3695 |
| 391C/AM | | 110 | 800 | 3722 | 3385 |
| ML-399A/AM | | 330 | 2000 to 3000 | 11,166 | 10,145 |
| ML-408/AM | | 18.3 | 100 | 619 | 550 |
| ML-443A/UM | | 120 | 800 to 1100 | 4060 | 3695 |
| ML-537/UM | | 115 | 1100 | 3900 | 3545 |
| ML-566/UM | | 280 | 4000 max. | 9500 | 8640 |

Lift of meteorological balloons at specified inflated volume, with hydrogen or helium.

# APPENDIX C

## Meteorological Equipment, Balloons

| Height Above Sea Level (Ft) | Atmospheric Pressure in mm Mercury | Pressure in Millibars (mb) | Temperature Degrees K |
|---|---|---|---|
| 0 | 760.0 | 1013 | 290 |
| 31,000 | 210.0 | 280 | 230 |
| 62,000 | 42.0 | 56 | 210 |
| 93,000 | 9.5 | 12.7 | 235 |
| 124,000 | 2.4 | 3.2 | 260 |

Atmospheric pressures and temperatures above the earth's surface.

Data available at U. S. Weather Bureau

at 110,000 feet  P = .2044 inches Hg  6.922 mb

T = -40 degrees F  -40 degrees C

.2044 x 2.54 = .519 mm at temperature of 233 degrees K

$$\frac{V}{V_1} = \frac{T}{T_1} = \frac{P_1}{P}$$

V = initial volume; T = standard temperature;

P = standard atmospheric pressure at sea level

$$V_1 = V \times \frac{T_1}{T} \times \frac{P}{P_1} = \frac{233}{273} \times \frac{760}{.519} = 1250V$$

1250 $ft^3$ would be contained in a sphere approximately 13.5 feet in diameter.

From Appendix B take the initial volume, multiply by 1250 for predicted volume at 110,000 feet. Compute diameter. As an example with balloon ML-391C: Initial volume = 110 cu. ft.

From 6.4.4 $D = \sqrt[3]{2V}$ approximately

$$= \sqrt[3]{220 \times 1250} = \sqrt[3]{275,000} = 65 \text{ feet.}$$

This example pertains to sounding balloons and the specific figures are for required burst altitude of 110,000 feet.